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A Comparative Investigation of Overhead Automated Material Handling System in a Sewing Floor of a RMG Industry in Bangladesh- A Case Study

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Abstract

After 4th Industrial Revolution (Industry 4.0) Ready Made Garments (RMG) in Bangladesh started adopting automation in production houses. The use of Automated Material Handling System (AMHS) was informed by the vision to improve productivity, efficiency of operations and the ability to respond faster to the ever-demanding market needs. It was supposed to transform the local production standards to international ones by smarter and data-driven manufacturing. Nonetheless, the question arises on whether indeed automation has achieved its own purpose as far as the RMG sector of Bangladesh is concerned. This paper will examine the relative effectiveness of Automated Material Handling Systems (AMHS) and Manually Material Handling Systems (MMHS) to learn whether automation has indeed been able to offer tangible benefits. The study is also intended to reveal the inherent factors, which could cripple the success of automation, including flexibility of the workforce, issues in the maintenance of the system or poor implementation, or a lack of fit with production settings. Moreover, the paper will suggest viable and sustainable solutions to overcome these issues, and it is important to note that automation cannot be successful unless technology is adopted. It relies on strategic planning, human integration that should be skilled, and constant improvement to get actual efficiency. The research finally brings in the insight into the ways in which the RMG sector in Bangladesh may maintain the balance between automation and human experience to secure the sustainability and productivity in the short and long run within the dynamic industrial environment.

Keywords

Automated Material Handling System (AMHS), Cycle time, SMV, Bottleneck, Efficiency.

1. Introduction

RMG sector is the foundation of Bangladesh's entire economy system, making substantial contribution to both employment factor and export revenue. As it is the most significant sector for the country's overall economic performance, it has become a center of focus for industrial experts to create more efficient, profitable, sustainable and ecological production floor to create market domination as well as match international standards. These approaches resulting from the introduction of Automated Overhead Material Handling System in production line. As experimented it should increase the production as well as efficiency of the production line. This paper discusses why it is not being able to serve the purpose.

1.1 Objectives

This paper will assess the performance of the overhead automated material handling system (OAMHS) in sewing floors of the RMG industry in Bangladesh and its practical applicability based on its efficiency in comparison with the traditional methods of handling materials. It is aimed at evaluating the impact on productivity, throughput, line balancing and labor usage and the bottlenecks, workflow problems and the operational constraints using both manual and automated methods and finally come up with information-based data to improve the system. The study is narrowed down to the selected sewing floors where OAMHS is adopted, with the emphasis on the cut-piece transportation, workstation loading behavior, production flow and operator performance, excluding the finishing and external logistics actions. The addressed problem appears because the line imbalance, bottlenecks, and unreliable performance results have been observed in factories implemented with OAMHS, frequently because of ineffective implementation, an inefficient way of loading, and ineffective workflow integration, that leaves the actual benefits and return of investment of automation in sewing operations unclear. This research is important because it complicates evidence-based assessments that underpin industrial engineers, factory managers, and decision-makers in streamlining the use of material handling systems to maximize production, minimize operational waste, enhance the overall competitiveness of the RMG sector in Bangladesh.

2. Literature Review

The study compares MMHS and AMHS in an FMS set up using the Analytic Hierarchy Process in terms of productivity, cost, and flexibility. Flexibility proved to be the prevalent aspect, and the preference went to the manual systems in the SME scenario. (Kumar Ojha et al., 2019).

In this report, an automated library branch is compared to a manual, and its effects on backlog, staff time, and customer service are analyzed. The automation almost eradicated the backlogs of materials and saved a lot of time and efforts of sorting and wasting them on customers. Annual savings of more than 228,000 dollars indicated that automation is a high value contribution to operations. (Ayre, 2009)

In the paper, the author separates the automation capabilities between discontinuous and continuous material handling machines. It examines sensor technology, control systems, and directional systems that are essential to automation success. The paper emphasizes the significance of integrated subsystems and semi-automation in processes, such as order picking. (Telek, 2023)

The thesis combines Materials Flow Mapping (MFM) and an alternative version of the Levels of Automation (LoA) taxonomy to find automation opportunities within a manufacturing logistics setting. The automation of storage and replenishment was identified to take over the lead time, with picking being a priority, which is very effective in identifying the disconnection between the existing manual processes. (Persson & Smedberg, n.d.)

This conference paper suggests the development of advanced gripper systems and adaptive control as the means of automatizing the process of fabric handling that takes up most of the sewing time. The model takes the form of fuzzy logic and neural networks to capture non-linear behavior of fabrics using real-time information. Although the approach has proven to be technically feasible, it is expensive, complicated, and has high levels of data dependency, which restricts its application in many industries. (*Advanced Robotics : Beyond 2000 : The 29th International Symposium on Robotics, 27th April - 1st May 1998, N.E.C., Birmingham : Conference Papers*, 1998)

Azad presents a multi-phase reshoring approach with strategic stages that involve the application of the Lean approach, Industry 4.0, digital twins, and modular cellular manufacturing. According to case studies, there is a substantial improvement in operation such as a decrease in lead time, reduction of waste, emission, and enhanced efficiency, and ROI. The framework also aligns workforce development compliance and sustainability certifications to help make reshoring decisions. (Azad, 2025)

This paper creates a smart robotic sewing machine based on a two-level control architecture that is a combination of fuzzy and neural networks. The technique enhances precision in sewing, particularly in tasks involving curved sewing edges, but fails with very flexible or slippery cloth and is limited to the manipulation of a single arm. It offers an AI-based solution but with evident scalability and material-handling constraints. (Huat, 2006)

The article discusses low-cost material handling solutions within the shirt manufacturing with a focus on reducing waste and ensuring sustainability in operations. The shopping-cart-based system suggested is more efficient but not as productive as the automated UPS solutions. The research indicates that future automation will bring good returns in the apparel material handling performance. (Jhanji, 2021)
Ku et al. combine machine vision and a modified sewing machine, being able to automate top-stitching based on YOLOv5 instance segmentation and advanced seam-path detection. Path smoothing evaluates the precision, which allows the high precision of consistent sewing. The system proves to be highly applicable in smart garment production that needs fineness in visual guidance. (Ku et al., 2023)

The current study uses the discrete-event simulation to enhance balancing of the lines during the process of trouser sewing and determine bottlenecks in the process through time studies and scenario testing. There is an increase in production of 42 percent, waiting period minimized and an overwhelming enhancement in balance of workstations. But the model does not consider real-world flexibility like machine failures and production of mixed style. (Kurşun Bahadır, n.d.)

Lee et al. introduces the automated system of the workflow of creating a smart sports bra with the application of integrated CAD, automated handling, cutting, and sewing systems. The system has a transfer accuracy of more than 96 percent, and it is only efficient when the design is simplified and symmetrical. The research shows that it is achievable in the case of individualized smart apparel but has significant drawbacks when it comes to extending it to more expansive and multifaceted garments. (Lee et al., 2021)

The study presents a robotic 3D sewing cell that involves the placement of fabrics on 3D molds and the sewing process using a robot-controlled sewing unit, which allows controlling the seam in space. The technique validates the technical feasibility of 3D robotic sewing but is only experimented with small scale products. The scale of industrial and complete integration of workflows is not well-developed. (Moll Philippand Schütte, 2009)
Naresh records change the batch-and-queue sewing to cellular flow in SAM, PFD allowances, and floating work balancing. The effect of the implementation was the reduction of WIP to a minimum and the quality improvement and flexibility of the cross-trained operators. Nevertheless, it is also restricted by factory limitations and incomplete in terms of ergonomic problems. (naresh, 2011)

The flexibility that is suggested by this work to create technology-enhanced sewing lines include model grouping and aggregate-group layouts design. The system enhances loading of equipment, performance measurements, and stability of the workforce. The methodology, though, is only applicable to sewing processes and cannot be extended to cutting or finishing departments. (Rajabova et al., 2022)

Seha et al. uses simulation to redesign the material handling with better layouts, pick-to-light machines, and AGVs. These interventions contribute greatly to the output rates, flexibility, and efficiency of transportation costs. The research supports the worth of simulation-based planning in planning lean material flow. (Seha et al., 2017) .

(Walter et al., 2009) provide the futuristic concept of apparel manufacturing that will change because of the introduction of robotics, automated handling, 3D digital design, and integrated information systems. Their structure highlights internet prototyping and intelligent networks to increase collaboration and efficiency. This paper gives a futuristic guideline on how to place apparel as a technology-advanced industry. (Walter et al., 2009).

Here A complete overview is given below: -

- The cost is high, and the technical difficulty does not enable people to adopt in SMEs despite the prospects of financial benefit in the long-term (Kumar Ojha et al., 2019); (Telek, 2023) similar things may happen in sewing too.
- Automation is also less efficient with flexible and delicate materials, particularly fabrics that are not uniform, and have the tendency to deform randomly (Huat, 2006); (Ku et al., 2023); (Moll Philippand Schütte, 2009).
- Most of the solutions are not scalable, and they only work in a controlled or small-scale setting (Moll Philippand Schütte, 2009); (Lee et al., 2021).

- The high degree of data reliance and advanced control systems lower the feasible industries that have low digital maturity (*Advanced Robotics : Beyond 2000 : The 29th International Symposium on Robotics, 27th April - 1st May 1998, N.E.C., Birmingham : Conference Papers*, 1998).
- The lack of flexibility in changing products and mixed production is also a significant limitation to operations in the field of apparel and logistics (Kurşun Bahadır, n.d.); (Lee et al., 2021).
- Automation may fit best in stable and predictable processes and is less applicable where variability, machine unavailability, or ergonomic complexity still exists (Persson & Smedberg, n.d.); (naresh, 2011).
- Not every process can be end-to-end automated, with these loopholes were human abilities, flexibility, or judgement must come into play (Jhanji, 2021); (Walter et al., 2009).

3. Methodology

The research was conducted manually on both sewing lines. We've used a stopwatch to record the times. To avoid human errors, we have taken 5 records and averaged them. All the calculations were done manually following necessary equations. Many processes are involved in this study. Considering those operations, a flowchart Figure 1. is given below: -

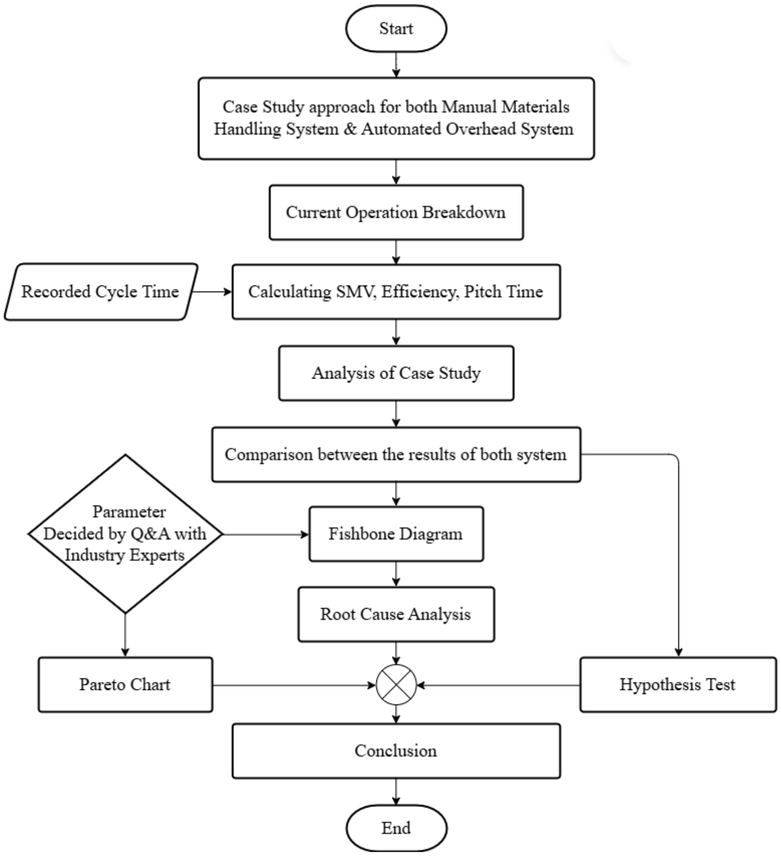

Figure 1. Process Sequence of the Case-Study

The given study is conducted with the systematic approach of comparing the Manual Material Handling System (MMHS) and the Automated Overhead Material Handling System (AOHMS) in the Ready-Made Garment (RMG) sewing floor. The following are the steps to present the methodology.

3.1 Case Study Approach

Both the manual and automated material handling systems were tested using a comparative method, which is the case study. Two distinct sewing lines that included a manually operated sewing line and an automated overhead sewing line were chosen to be analyzed in depth in case of similar production conditions.

3.2 Current Operation Breakdown

All the chosen sewing lines were observed and analyzed to reveal single operations. Specific activities were identified in the workflow to know how much each activity contributed to the overall cycle of time and efficiency of the production line.

3.3 Recording Cycle Time

The direct observation and time study methods were used in gathering cycle time data. The various readings were noted of each operation to obtain the precision and credibility of data, reducing human and environmental factors of error.

3.4 Computation of SMV, Efficiency and Pitch Time

The Standard Minute Value (SMV), line efficiency and the pitch time of each operation were calculated using the recorded cycle time. The following parameters proved vital in the comparison of productivity and the workload distribution in the two systems.

The term **SMV** means the time value arrived at for a task based on the average rate of output which qualified workers will naturally achieve without over exertion and **Pitch Time** means the average time taken per operation of the whole process. SMV is mainly calculated to determine the total time required for each product here pitch time determines required time per operations.

3.5 Case Study Analysis

Extended analysis has been conducted regarding all the gathered information (quantitative and qualitative). The parameters of the two systems were also compared to determine the overall system efficiency, throughput, and the ergonomic effectiveness of the system.

3.6 Comparison of Both Systems

Comparison of outcomes of SMV, efficiency, and cycle time calculations between MMHS and AOHMS was made. This step brought out performance enhancement by automation in handling materials.

3.7 Q&A with Industry Experts

Experienced industry professionals were talked over and interviewed through structured questionnaires to determine the important aspects that affect the performance of sewing lines. Their observations gave qualitative measures of quantitative data.

3.8 Development of Fishbone Diagram

According to the expert contributions and observation data, the Fishbone (Ishikawa) Diagram was developed to determine the possible causes of inefficiency in both systems. The factors were listed under general headings like Man, Machine, Method, Material and Environment.

3.9 Pareto Chart Analysis

The fishbone Diagram was created to identify the causes that were used to develop a Pareto Chart. The chart was used to establish which issues played the biggest part in inefficiency based on the 80/20 rule.

3.10 Root Cause Analysis

Root Cause Analysis (RCA) was performed in detail to find out the underlying problems that led to inefficiencies that emerged in both systems. The step incorporated the results of the Pareto and Fishbone analyses.

3.11 Hypothesis Test

Hypothesis test was used to statistically confirm the presence of a difference in the results of manual versus the automated systems. The test offered numerical confirmation of the changes that were noted.

3.12 Conclusion

The conclusion of the research summarized the results and provided a final opinion on the effects of automation on efficiency and productivity of operations including performance of the workers in the garment sector.

4. Data Collection

4.1 Collected data from sewing floor (Manual Material Handling System)

The flow of the process of the manual handling system sewing floor, shown in Figure 2, was carefully breakdown into individual operations to ease the process of data collection. The time spent at each step was accurately measured and noted to create the foundation of the following summary table. At the same time, a Time and Motion Study (TMS) was performed to identify and chart the possible causes of non-value-added time (waste) which negatively affect or have a potential negative effect on operator's efficiency.

Figure 2. Sewing Line with Manual Material Handling System

The sewing line was observed carefully. To understand each operation separately, a clear sewing line layout is generated and shown below in Figure 3.

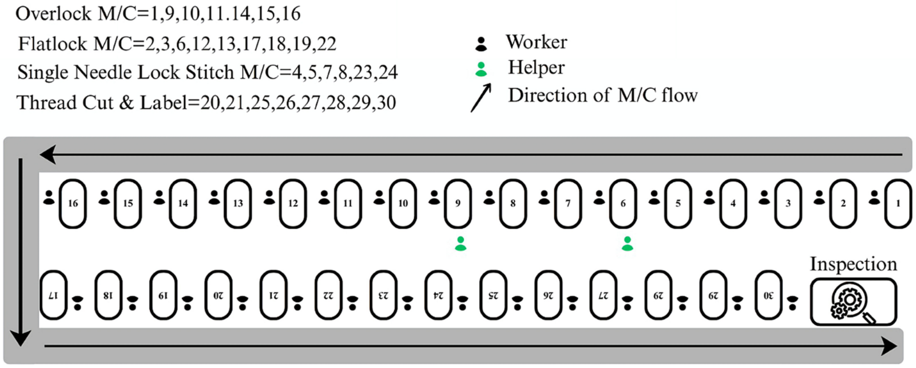

Figure 3. Layout of Sewing Line (Manual Material Handling System)

The cycle times and variation of processes were observed in each workstation. Through the gathered information, a comprehensive time study was performed to summarize average operation time, performance rating, and standard time of various sewing operations. There were 10 sewing lines on that floor. The time study was conducted on a basic T-shirt. From the sewing line we break down 17 operations, completing a fully finished T-shirt. These operations may require multiple number of machines as recorded in Table 1. Types of machines are also introduced. Each machine requires one operator, and it may require a helper too. All the necessary information is tabulated below in Table 1.

Table 1. Operation Breakdown of Regular T-shirt Production (Sewing Line with Manually Materials Handling system)

No	Name of the operation	Name of machine	No. of machines	Operator	Helper
1	Shoulder joint	Overlock M/c	1	1	
2	Shoulder top seam	Flatlock M/c	1	1	
3	Neck piping	Flatlock M/c	1	1	
4	Neck tuck	Single Needle Lock Stitch M/c	1	1	
5	Complete tuck/ Outer tuck	Single Needle Lock Stitch M/c	1	1	
6	Back tape attach	Flatlock M/c	1	1	1
7	Back tape edge	Single Needle Lock Stitch M/c	2	2	
8	Sleeve joint	Overlock M/c	3	3	
9	Arm hole top seal	Flatlock M/c	2	2	1
10	Side seam	Overlock M/c	3	3	
11	Sleeve hem	Flatlock M/c	1	1	
12	Turning + sticker out	Flatlock M/c	2	2	
13	Thread cut		2	2	
14	Bottom hem	Flatlock M/c	1	1	
15	Neck label	Single Needle Lock Stitch M/c	2	2	
16	Body hem & label thread cut		2	2	
17	Thread cut		4	4	
			30	30	2

In this sewing line, a total of 24 machines were used to complete the sewing of T-shirt. Thread Cutting operation doesn't require any machine. Total 30 operators and 2 helpers were assigned on the line.

4.1.1 Calculations from collected data

Based on the reading of cycle time for each operation, Average cycle time, Standard minute value, pitch time and later Efficiency is calculated, shown in Table 2. below-

Table 2. Time study for regular T-shirt (sewing line with Manual Materials Handling System)

Name of the operation	**Cycle time**					**Avg. cycle time**	**SMV**	**Pitch time**
Shoulder joint	9.11	9.3	9.43	9.02	8.56	9.08	0.17	0.0102
Shoulder top seam	7.67	7.8	6.67	6.76	6.9	7.16	0.14	0.0081
Neck piping	12.69	13.2	13.22	13.11	14	13.24	0.25	0.0149
Neck tuck	7.32	11.86	11.9	13.05	12.87	11.40	0.22	0.0129
Complete tuck/ Outer tuck	10.25	9.17	9.45	14.6	9.56	10.61	0.20	0.0120
Back tape attach	5.79	6.67	5.8	7.2	7.56	6.60	0.13	0.0074
Back tape edge	10.1	11.56	11.66	11.2	10.97	11.10	0.21	0.0125
Sleeve joint	23.75	22.87	23.1	22.12	21.33	22.63	0.43	0.0255
Arm hole top seal	14.58	14.21	15.6	15.44	14.89	14.94	0.29	0.0168
Side seam	25.1	26.4	25.47	25.98	24.49	25.49	0.49	0.0287
Sleeve hem	13.3	12.7	12.45	11.7	12.17	12.46	0.24	0.0141
Turning + sticker out	11.5	12.78	13.23	13.6	14.07	13.04	0.25	0.0147
Thread cut	15	15.76	16.11	14.79	14	15.13	0.29	0.0171
Bottom hem	7.88	7.4	8.12	8.55	7.69	7.93	0.15	0.0089
Neck label	18.4	16.34	17.58	19.33	19.27	18.18	0.35	0.0205
Body hem + label thread cut	13.08	12.8	13.9	15.55	13.89	13.84	0.27	0.0156
Thread cut	64	62	60	64	71	64.20	1.23	0.0724
							5.31	

From the data recorded in Table 2, further calculations are shown below: -

$$\text{SMV} = \frac{\text{Basic Time} + (\text{Basic time} \times \text{Performance Factor})}{60}$$

Performance factor=15%
SMV: 5.31min
Running Production: 1820 pcs
Working hour: 6 hours

$$\text{Pitch Time} = \frac{\text{SMV}}{\text{No of Operations}}$$

$$\text{Efficiency} = \frac{\text{Total production} \times \text{SMV} \times 100}{\text{No of Labors} \times \text{Working Hour} \times 60}\%$$

$$= \frac{1820 \times 5.31 \times 100}{32 \times 6 \times 60}\%$$

$$= 83.89\%$$

$$\text{Target Production} = \frac{\text{Working Hour} \times 60 \times \text{No of labor}}{\text{SMV}}$$

$$= \frac{6 \times 60 \times 32}{5.31}$$

$$= 2372\ pcs$$

4.2 Collected data from sewing floor (Automated Material Handling System)

The flow of the process of the Automated Overhead System Sewing floor, shown in Figure 4 and Figure 5 was carefully broken down into individual operations to ease the process of data collection. The time spent at each step was accurately measured and noted. At the same time, a Time and Motion Study (TMS) was performed to identify and chart the possible causes of non-value-added time (waste).

Figure 4. Sewing Line with Overhead Automated Material Handling System

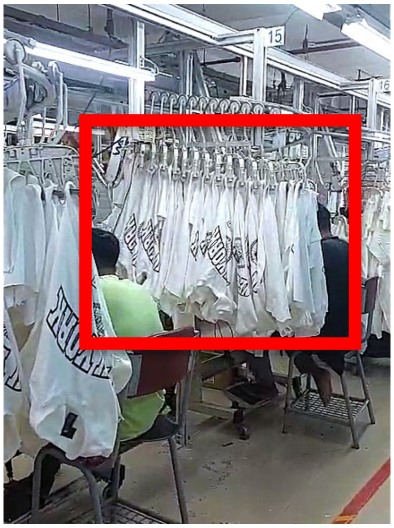

Figure 5. Probable Bottleneck Detected in Sewing Line

In Automated Overhead Material Handling System, the sewing Line is a bit difficult to understand as material movement is not linear. Materials here move inward and outward in each station. The mobile cut pieces come to a relevant sewing machine then sewn pieces move forward to next workstations according to the operation breakdown. Both the incidents and pick -place of materials occur simultaneously. Here is Figure 6. is given below to understand the sewing floor with Automated Overhead Material Handling System.

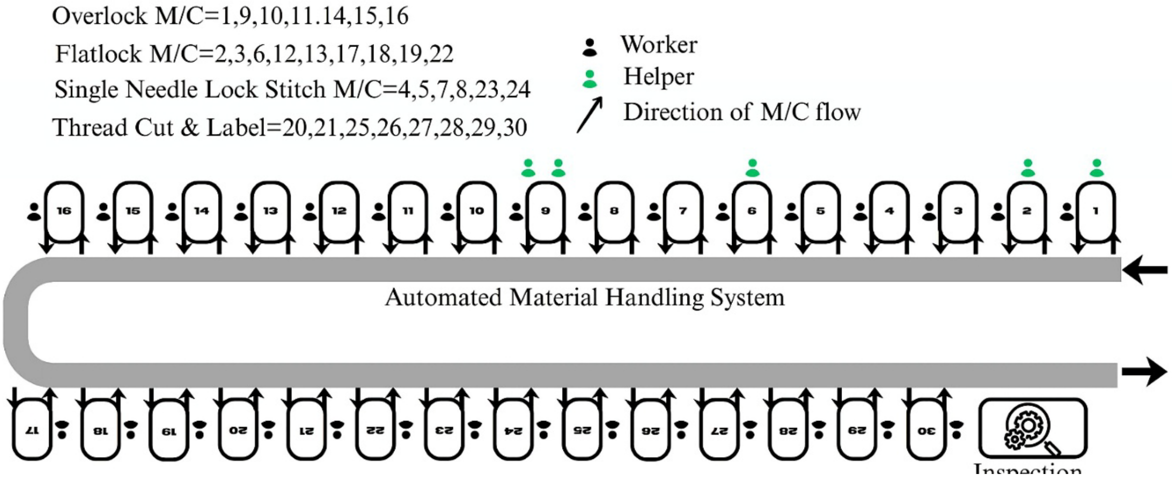

Figure 6. Layout of Sewing Line (Automated Overhead Materials Handling System)

We collected data from sewing floor with Automated Material Handling System like the previous one. A same product was selected to make an unbiased comparison. These operations may require multiple number of machines as recorded in Table 3. Types of machines are also introduced. Each machine requires one operator, and it may require a helper too. All the necessary information is tabulated below in Table 3.

Table 3. Operation Breakdown of Regular T-shirt Production (Sewing Line with AOMHS)

No	Name of the operation	Name of Machine	No of Machines	Operator	Helper
1	Shoulder joint	Overlock M/c	1	1	1
2	Shoulder top seam	Flatlock M/c	1	1	1
3	Neck piping	Flatlock M/c	1	1	
4	Neck tuck	Single Needle Lock Stitch M/c	1	1	
5	Complete tuck/ outer tuck	Single Needle Lock Stitch M/c	1	1	
6	Back tape attach	Flatlock M/c	1	1	1
7	Back tape edge	Single Needle Lock Stitch M/c	2	2	
8	Sleeve joint	Overlock M/c	3	3	
9	Arm hole top seal	Flatlock M/c	2	2	2
10	Side seam	Overlock M/c	3	3	
11	Sleeve hem		1	1	
12	Turning & sticker out	Flatlock M/c	2	2	
13	Thread cut		2	2	
14	Bottom hem	Flatlock M/c	1	1	
15	Neck label	Single Needle Lock Stitch M/c	2	2	
16	Body hem & label thread cut		2	2	
17	Thread cut		4	4	
			30	30	5

In this sewing line, a total of 24 machines were used, the same as the previous floor, to complete the T-shirt. Thread Cutting operation doesn't require any machine. Total 30 operators and 5 helpers were assigned on the line.

4.2.1 Calculations from collected data

Based on the reading of cycle time for each operation, Average cycle time, Standard minute value, pitch time and later Efficiency is calculated, shown in Table 4. below: -

Table 4. Time study for regular T-shirt (sewing line with Automated Overhead Materials Handling System)

Name of the operation	Cycle time					Avg. cycle time	SMV	Pitch time
Shoulder joint	9.23	9.39	9.32	8.97	9.14	9.21	0.18	0.0104
Shoulder top seam	11.46	7.97	10.24	6.76	7.99	8.88	0.17	0.0100
Neck piping	9.49	16.46	15.52	13.53	13.36	13.67	0.26	0.0154
Neck tuck	7.32	11.86	11.9	13.05	12.87	11.40	0.22	0.0129
Complete tuck/ outer tuck	13.71	9.15	18.46	8.8	16.84	13.39	0.26	0.0151
Back tape attach	5.2	7.76	4.69	9.24	9.26	7.23	0.14	0.0082
Back tape edge	9.26	13.35	11.54	11.95	13.02	11.82	0.23	0.0133
Sleeve joint	24.22	25.86	22.02	25.02	15.56	22.54	0.43	0.0254
Arm hole top seal	14.36	15.14	14.88	16.24	15.02	15.13	0.29	0.0171
Side seam	24.71	28.24	26.35	26.42	24.22	25.99	0.50	0.0293
Sleeve hem	13.93	12.58	12.94	10.62	12.66	12.55	0.24	0.0141
Turning + sticker out	9.84	16.17	13.25	20.63	14.07	14.79	0.28	0.0167
Thread cut	15.73	16.72	19.3	16.67	22.57	18.20	0.35	0.0205
Bottom hem	10.37	7.33	7.67	8.9	7.88	8.43	0.16	0.0095
Neck label	17.67	16.3	20.12	17.15	19.27	18.10	0.35	0.0204
Body hem + label thread cut	12.95	10.25	14.79	19.16	14.62	14.35	0.28	0.0162

Thread cut	91	65	60	64	67	69.40	1.33	0.0782
							5.66	

From the data recorded in Table 4., further calculations are shown below: -

$$\text{SMV} = \frac{\text{Basic Time } + \text{ Basic time} \times \text{Performance Factor}}{60}$$

Performance factor=15%
SMV: 5.66min
Running Production: 1590 pcs
Working hour: 6 hours

$$\text{Pitch Time} = \frac{\text{SMV}}{\text{No of Operations}}$$

$$\text{Efficiency} = \frac{\text{Total production} \times \text{SMV} \times 100}{\text{No of Labors} \times \text{Working Hour} \times 60}\% = \frac{1590 \times 5.66 \times 100}{35 \times 6 \times 60}\% = 71.37\%$$

$$\text{Target Production} = \frac{\text{Working hour} \times 60 \times \text{ No of labor}}{\text{SMV}} = \frac{6 \times 60 \times 35}{5.66} = 2228 \text{ pcs}$$

5. Results and Discussion

The result of the article is based on data gathered for both floors. At first the operation breakdown was collected. The breakdown includes operations number of operators, number of machines for a single style of a garment.

5.1 Table of Comparison

Table 5. shows a visible comparison between the two systems. Even after following same operations and similar machine requirements, all over production in Manually Materials Handling System is better than Automated Overhead Material Handling System.

Table 5. Comparison between both floor (Manually & Automated Overhead System)

Features	**Manual Handling System**	**Automated Overhead System**
No of Machines	30	30
Required Workers	32	35
SMV	5.31	5.66
Running Production	1820	1590
Efficiency	83.89%	71.37%
Target Production	2372	2228

From Table 5, it is crystal clear that the Manual Handling System is more efficient than Automated Overhead System. However, for more statistical analysis and comparison, a hypothesis test is conducted.

5.2 Hypothesis Test

The hypothesis test was done to determine the difference in performance between a Manually Handled System and an Automated Handled System in respect of operational efficiency (measured by cycle time). It was aimed to define whether the automation can offer statistically significant improvement in the conditions compared to manual handling, or it was still possible to state that the manual operations have better performance under the specified conditions. The similar working conditions and environments under which both systems were tested were done to provide a level of consistency. There were 17 separate observations (N =17) of measured cycle times in each system. Table 6. contains all necessary parameters to calculate the Hypothesis value.

Table 6. Table for Hypothesis Test analysis

Statistic	**Manually Handled System**	**Automated Handled System**
N	17	17
Mean	16.30	17.36
Std. Deviation (StDev)	13.35	14.30
Standard Error of Mean (SE Mean)	3.24	3.47

Data Collection: Both manual and automated systems data were gathered under direct observation and time measure of the same tasks under similar production environment. Every observation was the total time of one full working cycle (in seconds/minutes).

Difference:

Mean difference $= -1.062$

Standard deviation of differences $= 1.436$

Standard error of mean difference $= 0.348$

Confidence Interval (95% CI): (-1.800, -0.324)

t-value: -3.05; p-value: 0.008

Hypotheses:

Null Hypothesis (H_0): There is no difference between the mean performance of the manually handled and automated systems.

$$H_{0:}\ \mu_d=0$$

Alternative Hypothesis (H_1): There is a difference between the two means.

$$H_{1:}\ \mu_d\neq 0$$

Mean Difference:

- The mean for the manual system is 16.30.
- The mean for the automated system is 17.36.
- The mean difference (Manual – Automated) is -1.062, meaning the automated system's mean is about 1.06 units higher.

Confidence Interval:
The 95% confidence interval for the mean difference is (-1.800, -0.324).
Because 0 is not inside this interval, it suggests that the difference is statistically significant.
t-Test and p-Value:
t-value = -3.05 indicates that the observed difference is about three standard errors below zero.
p-value = 0.008 (which is less than 0.05) indicates that the result is statistically significant at the 5% level.

Analysis:

The negative value of the difference between means (-1.062) means that the manually operated system has lower average cycle time as compared to the automated system, which is faster in completing the same task. The confidence interval (-1.800 to -0.324) does not contain the value of zero, which implies that the difference is significant. The value of t (-3.05) indicates that the average difference is approximately three standard errors lower than zero, supporting the idea that the difference is not by chance. Moreover, p-value (0.008) is significantly lower than the significance level (a = 0.05), which proves that the observed difference is not significant. Essentially, the manual system has more consistency and can cover tasks quicker due to the conditions of the test environment, whereas the automated system might have suffered from setup delays, machine learning curves or mechanical adjustments that increased its average cycle time.

With reference to the statistical outcome: $p = 0.008 < 0.05$ = Reject H_0 Thus, statistically significant difference exists in the performance of the manually handled system and the automated handled system. The Manually Handled System is also more efficient (the mean cycle time is lower) than the Automated Handled System. This implies that manual handling still is more time-effective in the current state of operation. Nevertheless, through additional optimization and calibration of the system, automation may even be able to perform better than manual performance in terms of consistency and scalability.

5.2.1 Key Findings

- Manually Handling System is more productive, improved efficiency, less costly than Automated Overhead System.
- As Cycle time in Manually Handling System is less, the production (running & target) is higher than Automated Material Handling System.
- Unskilled Labor force creates time delay due to pick & place action.
- Untrained workers require extra helpers in critical operations in Automated Overhead System. As more worker is required, Efficiency is comparatively lower in Automated Overhead System.

5.3 Root Cause Analysis

Detailed Root Cause Analysis (RCA) was performed to find out the underlying problems that led to inefficiencies in both systems. The step incorporated by Q&A with industry experts on the results of the Pareto and Fishbone analyses. In Figure 7, the Fishbone Diagram is given considering all the root causes.

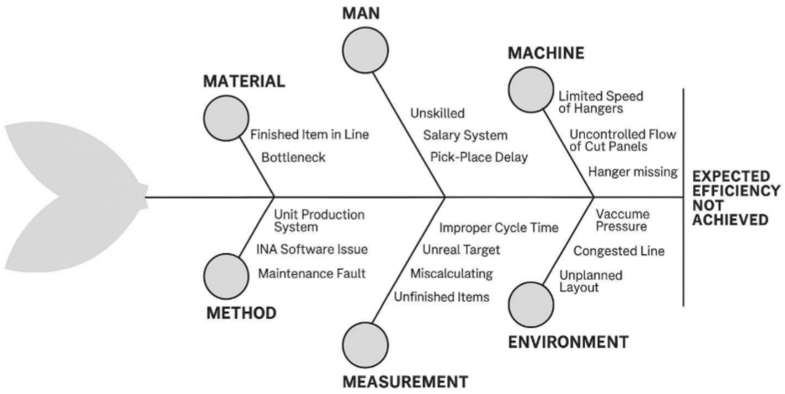

Figure 7. Fishbone Diagram for Root Cause Analysis

This is a Fishbone (Ishikawa) Diagram of the root causes of the problem of "Expected Efficiency Not Achieved." It identifies six key factors of potential problems: Man, Machine, Material, Method, Measurement and Environment, which include certain problems, including unskilled workers, bottlenecks, unplanned layout and improper cycle time, among others, these are all problems that prevent the efficiency of production process. While relating causes with their roots, we deeply observed deeply while reading cycle time. Then all reasons were cross checked and discussed with experts and then categorized. The impact of root causes on the process is also assessed.

5.4 Pareto Chart from Root Causes

In Table 6. Various root causes from fishbone diagram are weighted along with the impact ratings. Later, the cumulative values of each cause were determined.

Table 6. Table for Pareto Analysis

Root Cause	**Justification**	**Category**	**Weight (1–10)**	**Impact Ratings**	**Cumu-lative**
Unskilled	Major impact on performance	Man	10	8.62%	8.62%
Unplanned Layout	Structural constraint on efficiency	Environment	8.67	7.47%	16.09%
Unfinished Items	Causes rework and inefficiency	Measurement	8.33	7.18%	23.28%
Bottleneck	Major cause of low line efficiency	Material	8	6.90%	30.17%
Vacuum Pressure	Occasional machine-related delay	Environment	7.67	6.61%	36.78%
Salary System	Indirect effect on motivation	Man	7.67	6.61%	43.40%
Maintenance Fault	Affects uptime directly	Method	7.33	6.32%	49.72%

Unit Production System	Structural inefficiency	Method	6.67	5.75%	55.47%
Finished Item in Line	Increases WIP	Material	6.67	5.75%	61.22%
Limited Speed of Hangers	Directly reduces throughput	Machine	6.33	5.46%	66.67%
Pick-Place Delay	Affects flow and speed	Man	6.33	5.46%	72.13%
INA Software Issue	May cause data or control lag	Method	6	5.17%	77.30%
Hanger Missing	Delays operations intermittently	Machine	6	5.17%	82.47%
Uncontrolled Flow of Cut Panels	Causes imbalance in process	Machine	5.33	4.59%	87.07%
Congested Line	Physically limits smooth flow	Environment	5.33	4.59%	91.66%
Miscalculating	Affects planning accuracy	Measurement	4.33	3.73%	95.40%
Improper Cycle Time	Misaligned targets reduce output	Measurement	2.67	2.30%	97.70%
Unreal Target	Creates planning gaps	Measurement	2.67	2.30%	100.00%
			116	100.00%	

A Pareto Diagram shown below (Figure 8.) regarding the root causes found from the Fishbone Diagram. From Table 6. The cumulative values are used for developing pareto analysis.

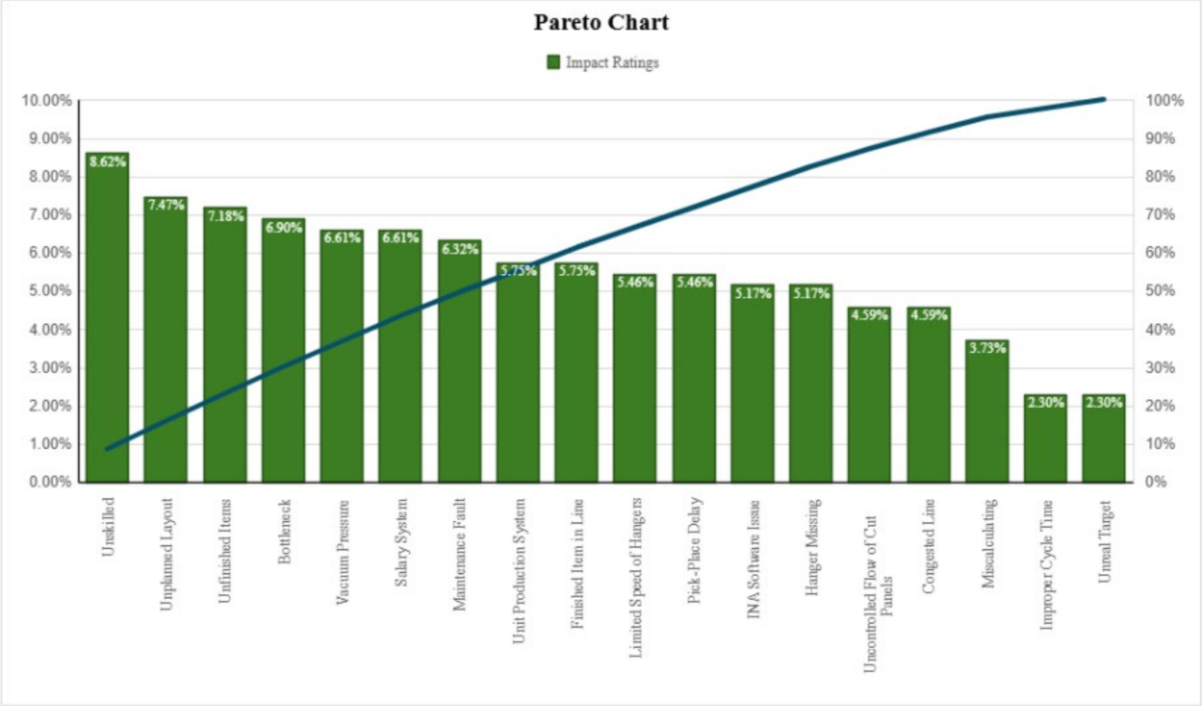

Figure 8. Pareto Analysis based on the Root Causes

From the chart, it is crystal clear that unskillful labor, unplanned layout, bottleneck, and unfinished items in line are the main reasons for being an ineffective sewing line. After Pareto Analysis, key findings were added.
From pareto analysis, these are the reasons responsible for 80% of being less efficient:

- Unskilled
- Unplanned Layout
- Unfinished Items
- Bottleneck
- Maintenance Fault
- Unit Production System
- Finished Item in Line
- Limited Speed of Hangers

- Vacuum Pressure
- Salary System
- Pick-Place Delay
- INA Software Issue

From the pareto analysis we can say by focusing on addressed problems above 80% of root causes can be eliminated and enhanced efficiency can be obtained.

6. Conclusion

The above comparative study has shown important insights into how Automated Overhead Material Handling Systems (AOHMS) and Manual Material Handling Systems (MMHS) performed in sewing floor of Bengali RMG industry. Even though the automation was implemented to improve productivity, precision, and adherence to international standards of manufacturing, the study results show that the perceived results are not yet reflected in full.

The time studies, SMV analysis and efficiency analysis had empirical data showing that the manual system had better productivity (1820 pcs) and efficiency (83.89 percent) in the same working condition than the automated overhead system which realized 1590 pcs with 71.37 percent efficiency. Even with the advantages of technology, the automated system exhibited an operational delay mainly because of the non-skilled workforce, layout based on inefficiencies, and a high level of helper dependency and limitation of the equipment used such as a lower hanger speed and software malfunctions.

Root Cause and Pareto analyses further supported these observations, pointing out that ninety percent or so of performance loss is due to few, large issues chiefly unskilled operators, unplanned layouts and workflow bottlenecks. These aspects negatively affect the possible benefits of automation as they make the flow of materials disrupted and cause more of the non-value-added time. The statistical analysis Hypothesis test proved the significant differences in the performance of the two systems and justified that automation does not necessarily result in better efficiency without proper process design and adaptation of the workforce.

The study in a nutshell underlines the fact that to attain true productivity gains, integration of technology should come with the development of human skills, ergonomic planning, and optimization of the system. The findings suggest that although AOHMS has long-term modernization potential, it cannot be used with high efficacy in the Bangladesh RMG setting in short-term unless it is accompanied by systematic training interventions, continuous maintenance and process balancing, which is based on the data.

Thus, the way forward of the RMG sector cannot be the uninformed running towards automation but rather a mix-up of lean manufacturing concepts and a specific automation and human centered design. This balanced solution will be the key to ensure efficiency improvement, stability of the working force, and the ability to stay competitive in the global apparel market.

A combination of improvement strategies is required to overcome the challenges identified in the production line, which should consider all human, process, machine, material, and management factors to improve. Proper training on skill development and performance-based incentives should be offered to the workers, and this should be provided with a fair and well-structured system of offering salary to enhance motivation and efficiency. Production arrangement should be re-engineered to promote smooth flow of work without any bottlenecks and unnecessary flow of unfinished or finished products due to improved visualization and balancing of production lines. Periodic preventive maintenance should be adopted to correct the defects associated with the vacuum pressure, hanger speed, and other machine errors, whereas software-related errors like errors of INA system should be addressed with the help of IT support and the cooperation with the vendors in time. The movement of materials can be enhanced by marking materials clearly, proper segregation and buffer points at critical points. At the management level, establishing a cross-functional improvement team, providing adequate budget on maintenance and training, establishing accountability on vendors and a continuous improvement culture will guarantee a sustained improvement. All these coordinated actions will increase efficiency, stabilize the work of automation, and make the technology integration into the production system smoother.

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